SCIENTIFIC ENQUIRY AND ITS PLACE IN THE NATIONAL CURRICULUM

SUMMARY OF A SEMINAR ORGANISED BY SCORE

19 SEPTEMBER 2011

This is a report of a SCORE workshop held on 19 September at the Royal Society. The report summarises the main issues raised and describes the views of the participants.

The report does not represent SCORE policy.

MAIN FINDINGS OF THE SEMINAR

- The aspects of 'scientific enquiry' identified by the delegates at the event for inclusion in the statutory National Curriculum for Science at both primary and secondary levels are: Methods of Science – the design of experiments and investigations; making measurements; presenting and evaluating data; and looking for patterns and relationships in data; risk assessment (primary) and risk and uncertainty (secondary); and The Nature of Scientific Knowledge. At secondary level, the ideas that are defined by Institutions and Social Practices of Science should also be in the National Curriculum.
- The aspects of 'scientific enquiry' identified for the wider school curriculum at primary level are: the Institutions and Social Practices of Science; and Science in Society.
- The aspects of 'scientific enquiry' identified for the wider school curriculum at secondary level are those that come under Science in Society.
- The Nature and Methods of Science is a more appropriate working title for this area of the curriculum than either 'scientific enquiry' or How Science Works, and should be used in future discussions.
- 'Scientific enquiry' needs to be made explicit in the National Curriculum but how it is embedded and contextualised will need further work.
- There was support for the model of progression described in the ASE publication *Is it fair or isn't it?* for primary school children.
- Since assessment dictates what is taught, especially at KS4, how 'scientific enquiry' will be assessed should be considered when the curriculum is written.

BACKGROUND

The Government is currently carrying out a review of the National Curriculum in England for 5–16-year olds. It is the Government's intention to slim down the number of subjects in the National Curriculum and state only the essential knowledge in key subjects that every pupil should acquire to make appropriate progress. A slimmed down National Curriculum will allow schools greater freedom to develop a wider school curriculum that is appropriate to their cohorts and which focuses on pedagogy and on the contextualisation of knowledge and concepts. These revisions are being informed by international best practice and engagement with the subject communities.

Science is to remain a core subject in the National Curriculum, and will remain part of the wider school curriculum. Currently, the statutory National Curriculum for Science will include a Programme of Study for each of Physics, Chemistry and Biology and will also encompass what is currently termed by the Department for Education (DfE) as 'scientific enquiry'.

An understanding of the various aspects of 'scientific enquiry' has been a component of the National Curriculum for Science since its launch in 1989. The content of this area of work and its place in the curriculum have, however, changed over the years. The current version of the National Curriculum, introduced in 2005, established the term 'How Science Works' (HSW) to reflect that 'scientific enquiry' was not just a set of experimental skills but should also convey an understanding of how scientific knowledge has been and continues to be developed.

In light of the Government proposals, SCORE recognises the need to develop a position on what aspects of 'scientific enquiry' or 'HSW' should be in the statutory National Curriculum for Science and how these should be expressed, and what aspects should be left to the wider schools' curricula.

This workshop, by drawing on the expertise of the wider scientific community, discussed 'scientific enquiry' in terms of what all 11-year olds and all 16-year olds should be able to do and understand, including ideas that they should have developed. This would inform the SCORE position on what aspects of 'scientific enquiry' should be statutory.

The workshop also aimed to gather some consensus on:

- whether 'scientific enquiry' should be separated from, or integrated within, the Programmes of Study for Biology, Chemistry and Physics in the National Curriculum;
- what terminology should be used to describe 'scientific enquiry';
- what progression in 'scientific enquiry' might look like;
- how 'scientific enquiry' should be assessed to achieve the curriculum aims.

THE WORKSHOP

The workshop was chaired by Libby Steele, Head of Education at the Royal Society.

The group discussions were preceded by two presentations on the findings of research, commissioned by SCORE, into how HSW is dealt with in the National Curriculum in England and in the national curricula of other countries.

International comparisons

Vicky Wong described how HSW is approached in the 5–16 national curricula in Hong Kong and in Alberta, Canada. These countries were chosen for the study because they performed highly in the latest 2009 Programme for International Assessment (PISA) and their curricula are available in English. It should be noted that the science curricula for 14–16-year olds in both Hong Kong and Alberta are aimed at different cohorts to the KS4 curriculum in England. In Hong Kong science is optional at this level and in Alberta special provision is made for less able and for the most able students – in contrast, in England, the KS4 curriculum is aimed at all students. Therefore, any comparisons made between these three countries need to take this into consideration.

Vicky tracked the following aspects of the curricula:

- scientific investigation, including, for example, experimental design, making measurements, presenting and evaluating data, looking for patterns and drawing conclusions etc;
- science, technology and society;
- values and attitudes;
- the nature of science;
- health and safety; and
- institutions and social practices of science[1].

Education in Hong Kong is similar to England in that it is divided into key stages and content is specific to each key stage. The curriculum is described by five Key Learning Areas, one of which is Science Education. Generic skills – much of which England refers to as HSW – run through all key areas.

[1] This research did not look at 'working collaboratively with others', 'communication of scientific ideas' and 'problem-solving skills'.

At primary level, science is covered in General Studies, one of four core subjects, which also includes technology and the humanities. Primary science places a strong emphasis on attitudes, values and skills, which are all assessed. There is also more emphasis on writing-up experiments compared to the English curriculum. At both primary and secondary levels there are 'extension' activities aimed at the most able pupils and these are mainly what England would define as HSW activities.

Science features in all three secondary programmes – the main curriculum, the applied learning programme for less able pupils, and in the special needs education programme – but it is optional for everybody. Science is not a core subject at KS4, and pupils can choose one of several science options or no science. Each science defines its own version of HSW. The result is that if pupils take all three sciences at KS4, they will get a broader coverage of HSW than defined by this research.

In Alberta, the curriculum is specified in detail per year and students are organised in grades. Science is compulsory to Year 12 (18-year olds), though separate provision is made for less able pupils and for the most able.

Every content statement is mapped to a HSW statement. At primary level there is an emphasis on 'attitudes to science', at secondary level the emphasis is on one of the following areas: the nature of science, science and technology, or social environment.

Assessment of How Science Works

Andrew Hunt provided a summary of the SCORE-commissioned research he did into the assessment of HSW at GCSE[2]. The research identified a list of what is assessed in relation to HSW in the current GCSE science written examinations in England and Wales. This list provides SCORE with a starting point to identify what aspects of HSW should be included in the National Curriculum for Science. Table 1 summarises the main ideas about science in relation to HSW identified by the research.

TABLE 1

A SUMMARY OF THE MAIN IDEAS ABOUT SCIENCE RELATED TO HSW IN GCSE EXAMINATIONS

1–4: Methods of Science

1. The design of experiments and investigations
2. Making measurements
3. Presenting and evaluating data
4. Looking for patterns and relationships in data

5. The Nature of Scientific Knowledge

6. The Institutions and Social Practices of Science

7–8: Science in Society

7. Assessing the impacts of science and technology
8. Making decisions about science and technology

Andrew pointed out that the UK science curriculum has a broader, more appropriate and modern interpretation of HSW than either Hong Kong or Alberta. While the national curricula of Hong Kong and Alberta focus almost entirely on investigations done in the laboratory, KS4 pupils in England are exposed to other forms of 'scientific enquiry', including field work, observational studies as demanded by geology, ecology and astronomy, and epidemiological studies.

[2] Report to SCORE, Andrew Hunt, 2010, Ideas and evidence in science; lessons from assessment

GROUP DISCUSSIONS

The participants split into groups of two: one group focused on what all 16-year olds should be able to do and understand, and the other focused on what all 11-year olds should be able to do and understand, in relation to 'scientific enquiry'. Both groups used the list of ideas about science that are currently assessed at GCSE as a starting point for discussion (see Table 1). The participants agreed, however, that the statements in Table 1 should not be viewed in isolation but must be set in a scientific context, and that scientific knowledge should be combined with methods of enquiry. The ASE book, *It's not fair: or is it ?*, provided further guidance for the primary science group. Both groups were also asked to consider the PISA headings for 'scientific enquiry' because of the increasing importance the Government is placing on international comparisons in its revision of the National Curriculum.

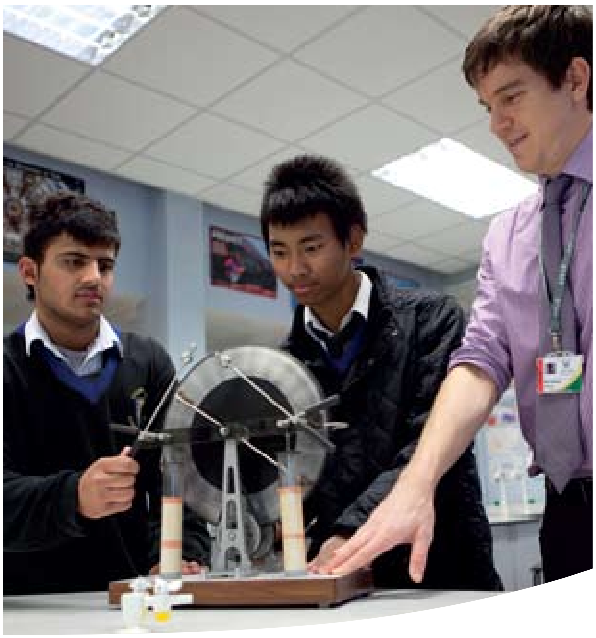
The consensus reached by the groups assumes (see Table 2) everybody is taught a core from which they can progress onto other science courses, if that is their intention. The statutory core does not differentiate between the needs of future scientists and non-scientists. This will be dealt with in the wider school curriculum.

TABLE 2

ELEMENTS OF SCIENTIFIC ENQUIRY THAT SHOULD, AND SHOULD NOT, BE INCLUDED IN THE STATUTORY NATIONAL CURRICULUM FOR SCIENCE AS IDENTIFIED BY THE DELEGATES

Scientific enquiry	Primary	Secondary
METHODS OF SCIENCE: **1.** The design of experiments and investigations **2.** Making measurements **3.** Presenting and evaluating data **4.** Looking for patterns and relationships in data	All statements defined under this section should be included. In general, ideas covered by Methods of Science are done well at primary level. This section could usefully include explaining the rationale behind a project, and 'observation' should be included under 'Making measurements'. Some of the ideas under 'Presenting and evaluating' would be better placed in other sections. For example, the statements on evaluating evidence would be better placed under 'Looking for patterns in relationships and data'.	All statements defined under this section should be included. All pupils, regardless of their future careers, need to be able to make sense of data in order to be scientifically literate. All pupils, especially those going on to study science post-16, need to appreciate that 'scientific enquiry' is not just a set of routine operations designed to generate data or a predominantly essay-writing task, and involves higher-level tasks such as the critical evaluation of data. Practical skills are useful not just for future scientists but for students who will go on to become plumbers, electricians, technicians etc, who need to use their knowledge in a practical way. Practical capability should not be solely lab-based work, but field work and observational studies are as important. Risk and error, could be integrated into Methods of Science.

TABLE 2		
Scientific enquiry	**Primary**	**Secondary**
5. The Nature of Scientific Knowledge	All statements defined under this section should be included, but with some modification. Primary school children should be encouraged to explore their own ideas and form their own explanations and question them. Specific tasks, including historical, scientific case studies, could be used to help them develop knowledge in this area. The statements that focus on theories and explanations, should not be in the statutory National Curriculum but 'Scientific explanations are valid when the evidence supports them' should be added . The statement on 'scientific explanations' should be changed so that the focus is on the pupils' own explanations. It is important to emphasise that explanations may change given new evidence or interpretations. Primary school pupils need help to make links between data and predictions, and between what they know and understand and key big ideas.	All statements defined under this section should be included. All pupils should appreciate that science isn't just a collection of facts but comprises theories developed by scientists that can change over time. This could be taught and learnt using case studies, and textbooks could be revised along these lines.
6. The Institutions and Social Practices of Science	All statements defined under this section should not be included.	All statements defined under this section should be included. All pupils should appreciate the role of peer review and its role in the publication and value of scientific data.
SCIENCE IN SOCIETY **7.** Assessing the impacts of science and technology **8.** Making decisions about science and technology	The statements under 7 and 8 could be left to the wider schools' curricula, except for those which refer to risk assessment, as relevant to primary children, ie health and safety issues, which would be better placed in Methods of Science. How scientists help people to 'look at the part science has played in the development of many useful things' – could also usefully be placed in Methods of Science.	The statements under 7 and 8 could be left to the wider schools' curricula, except for those which refer to risk and uncertainty, which could be integrated into Methods of Science. Based in part on the poor quality of GCSE exam questions on Science in Society, there may be an argument for leaving this aspect of 'scientific enquiry' to A-level biology, chemistry and physics.



Progression

The primary science group agreed that it was important to recognise the way primary pupils develop 'scientific enquiry' skills as they go through schooling.

There was support for the model of progression described in the ASE publication *Is it fair or isn't it?* This states that children become increasingly autonomous in their decision-making; systematic and accurate in collecting and analysing data;and able to express their ideas scientifically using scientific language and enquiry. How successful this model is comes down to children being given opportunities to use their skills in contexts that progress. Some examples include progressing from simple tangible ideas to complex, more abstract ideas; from investigating familiar things to investigating unfamiliar things; from observing everything to observing only what is relevant; and from testing ideas using evidence to understanding the nature of evidence, and if it can be trusted.

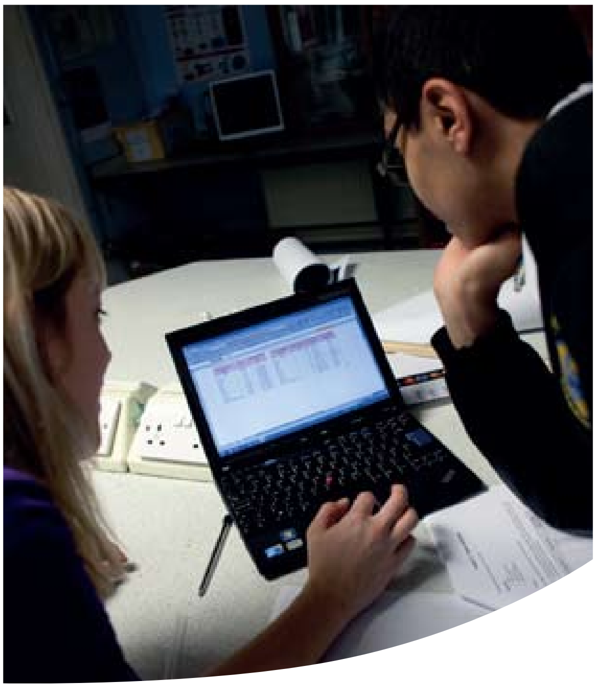
Assessment

While the National Curriculum dictates what is taught, not what is assessed – the point was made that there is no requirement to assess something because it is in the National Curriculum – assessment is a big driver in secondary education. It would be better, therefore, to accept this and to think how an idea will be assessed when the curriculum is written. This would place the science community in the driving seat of the curriculum rather than the Awarding Organisations, as is currently the case.

The SCORE-commissioned research into the assessment of HSW identified a bank of question items from external written examinations for each of the categories defined in Table 1. The participants agreed that this bank of questions should be more widely available because they go some way to being able to ascertain whether or not an idea can lead to useful and worthwhile learning.

It is important to realise that the statements under the headings in Table 1 originate from written test items, which means that the assessment of practical and hands-on skills are missing. As it stands this implies 'scientific enquiry' can be assessed through written exams without the need for practical work – there was consensus that this is a decision that needs to be made consciously rather than by default.

As one of the delegates pointed out, pupils can get an A grade in controlled assessments on the strength of their write-up, there are no marks for practical skills. The danger is that if practical skills are not assessed they will not be taught.



TERMINOLOGY

What this part of the curriculum is called will be important. Ultimately, however, whatever title is given, it will be defined by what comes under it. The term How Science Works (HSW) was shrouded in confusion because of the lack of consensus among Awarding Organisations on what HSW is. The problem with 'scientific enquiry' is that it is doesn't capture both the need to understand the ideas of science and how these ideas have developed, and scientific activity. Moreover, internationally 'scientific enquiry' is used to describe a pedagogy as well as curriculum content – eg enquiry-based learning – so this term could lead to confusion.

The group agreed that, in light of the discussions, the Nature and Methods of Science would be an appropriate working title for future discussions in this area.

STRUCTURE

Several models were proposed for positioning 'scientific enquiry' in the National Curriculum.

- As a stand alone unit at both primary and secondary levels but with the requirement to teach the material embedded within the substantive content.
- Embedded within the primary Programme of Study for Science, but a stand alone unit at secondary level.

- Totally embedded within the Programmes of Study for Physics, Chemistry and Biology in the National Curriculum at both primary and secondary levels.
- Not specified in the Programme of Study for Science but embodied in the overall aims of the science curriculum.
- Not specified in the Programme of Study for Science but stated as required outcomes.

There was agreement among the delegates that 'scientific enquiry' needs to be made explicit in the National Curriculum but how it is 'embedded' and contextualised will need further thought and guidance. Some teachers 'embed' this aspect of the curriculum into their teaching naturally but it cannot be assumed that all teachers, especially those without a science background, will do this.

One recommendation, the delegates agreed, would be to present 'scientific enquiry' in the different options and obtain evidence on what works best.

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